

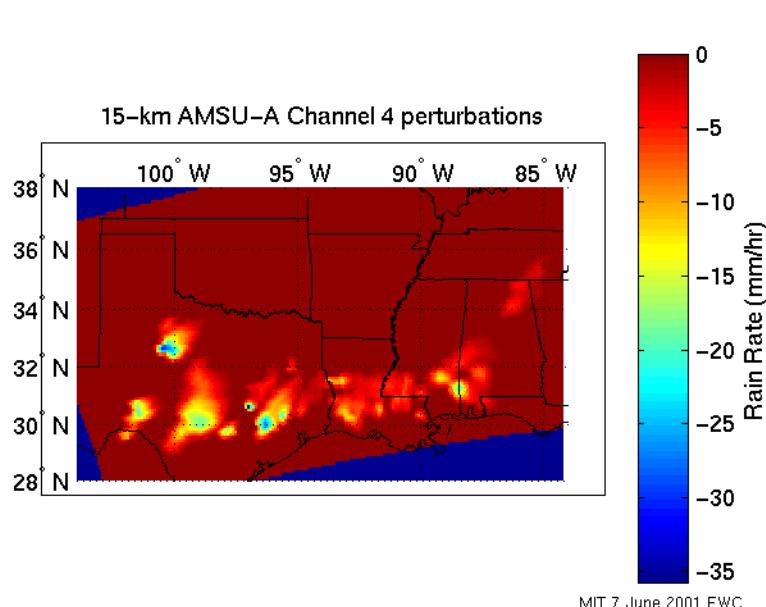
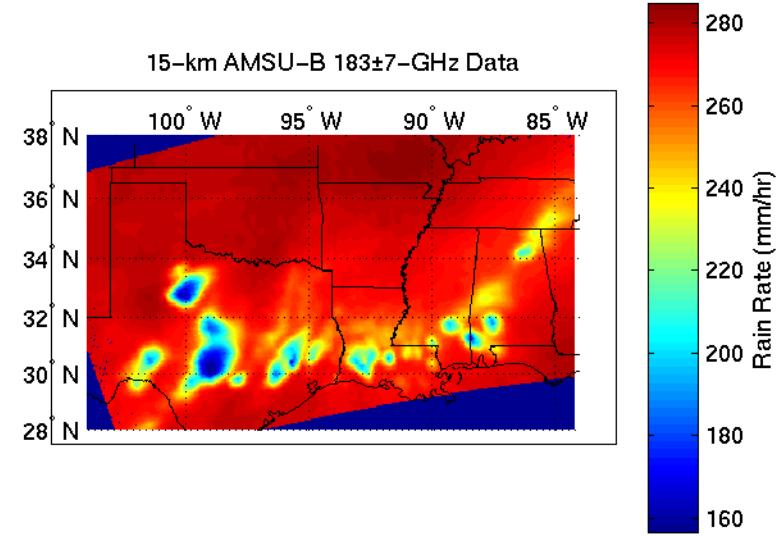
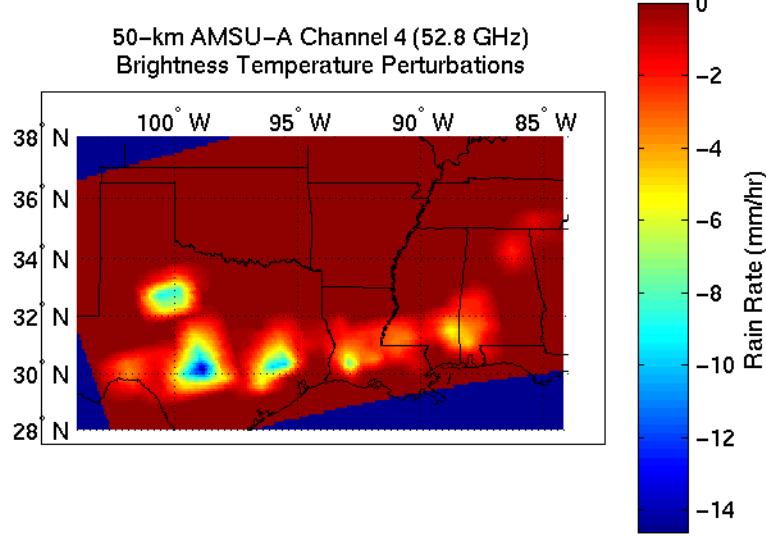
# **RECENT RESULTS USING AMSU, NAST, AND MIR: PRECIPITATION, HUMIDITY PROFILES, AND CLOUD CLEARING**

David H. Staelin, William J. Blackwell, Fredrick W. Chen, and Jay Hancock

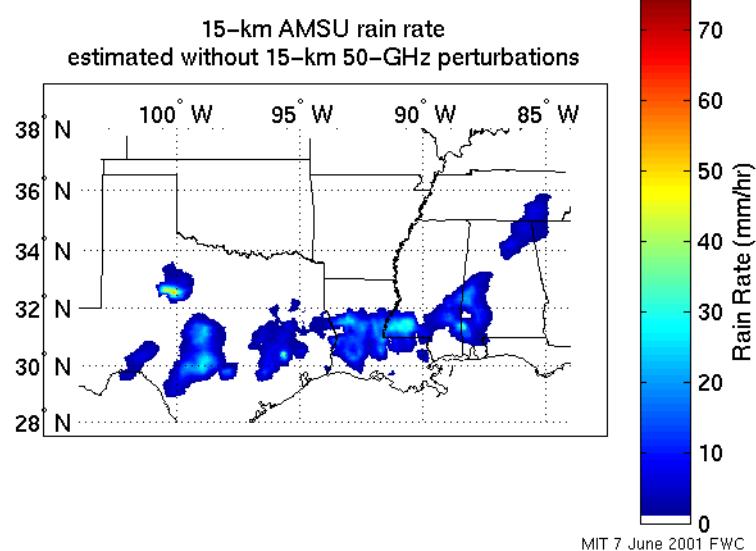
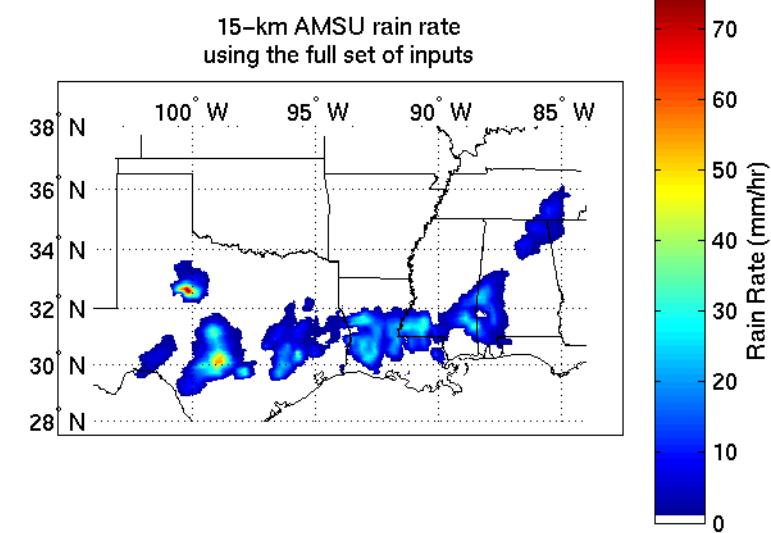
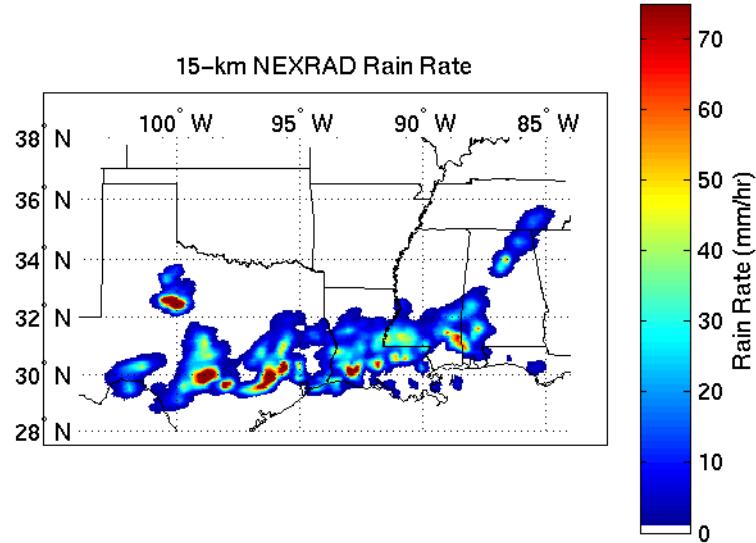
AIRS SCIENCE TEAM MEETING  
PASADENA CALIFORNIA  
June 19-21, 2001

## **OUTLINE**

- X Improved precipitation rate estimates at 15 and 50 km using AMSU-A/B data
- X Humidity profile retrievals using NAST-I plus 54- and 183-GHz spectral data
- X Simulated cloud clearing results using AIRS and AMSU data



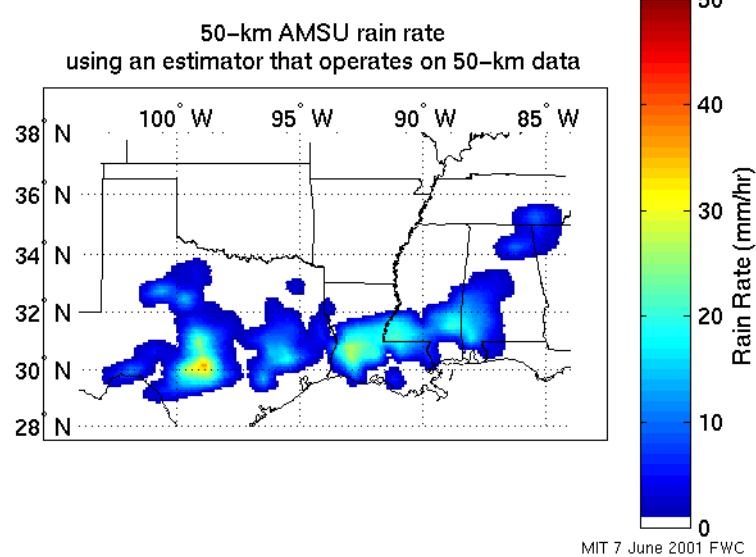
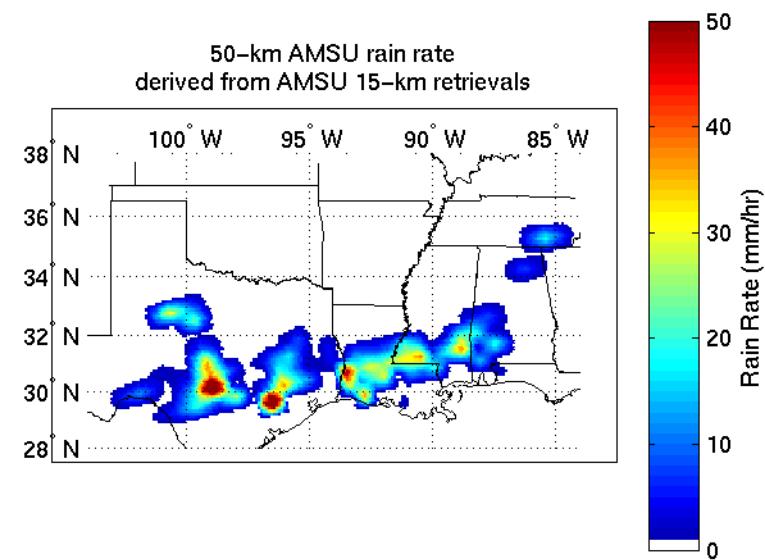
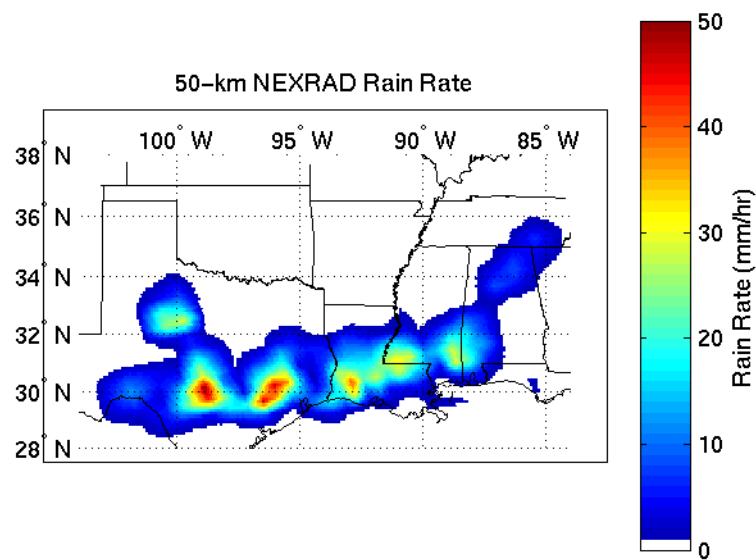
Sharpening of  
AMSU-A brightness temperature perturbations  
from 50-km resolution to 15-km resolution  
13 Sept 2000, 0117 to 0119 UTC



Comparisons of 15-km NEXRAD rain rate  
and 15-km AMSU rain rate retrievals  
13 Sept 2001, 0117 to 0119 UTC

Top right: the full set of inputs includes 15-km AMSU-A brightness temperature perturbations in the 54-GHz band, temperature profile principal components, water vapor profile principal components, AMSU-B data from the 183-GHz band, and the cosine of the scan angle

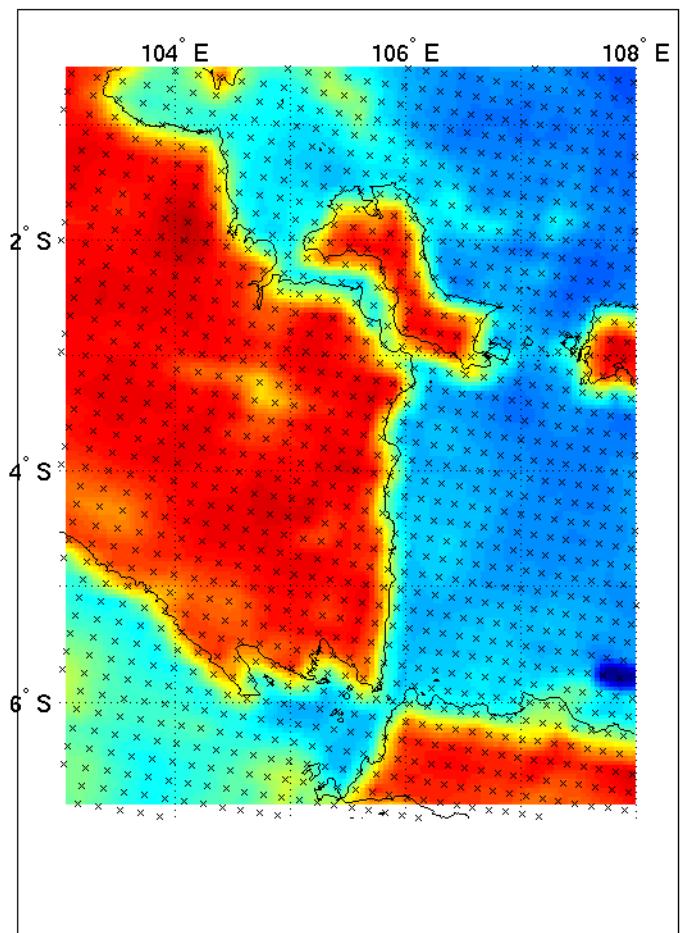
Bottom left: this image was produced using an estimator that used the full set of inputs without the 15-km brightness temperature perturbations from the 54-GHz band



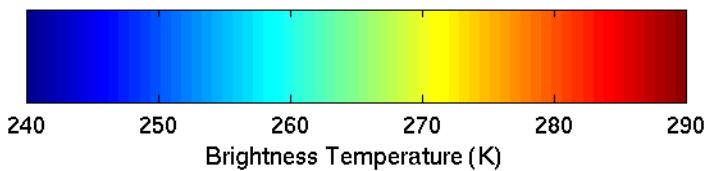
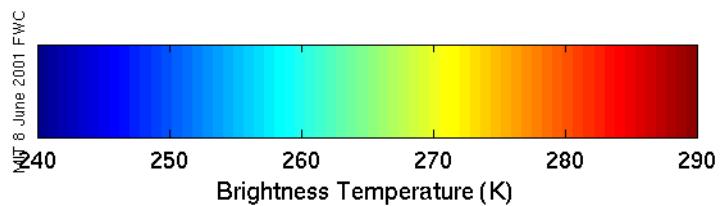
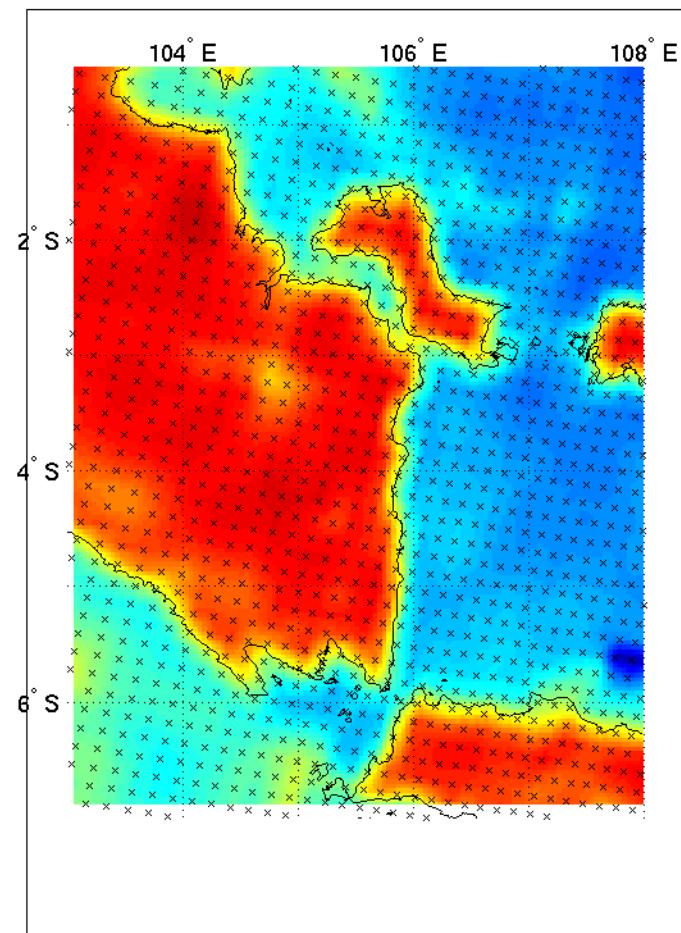
Comparisons of 50-km NEXRAD rain rate  
and 50-km AMSU rain rate retrievals  
13 Sept 2001, 0117 to 0119 UTC

MIT 7 June 2001 FWC

AMSU-B 89.0-GHz Data  
25-Jan-2000, 00:16 to 00:18 UTC



AMSU-B 89.0-GHz Data  
With Location Correction



# AMSU Geographic Information Correction

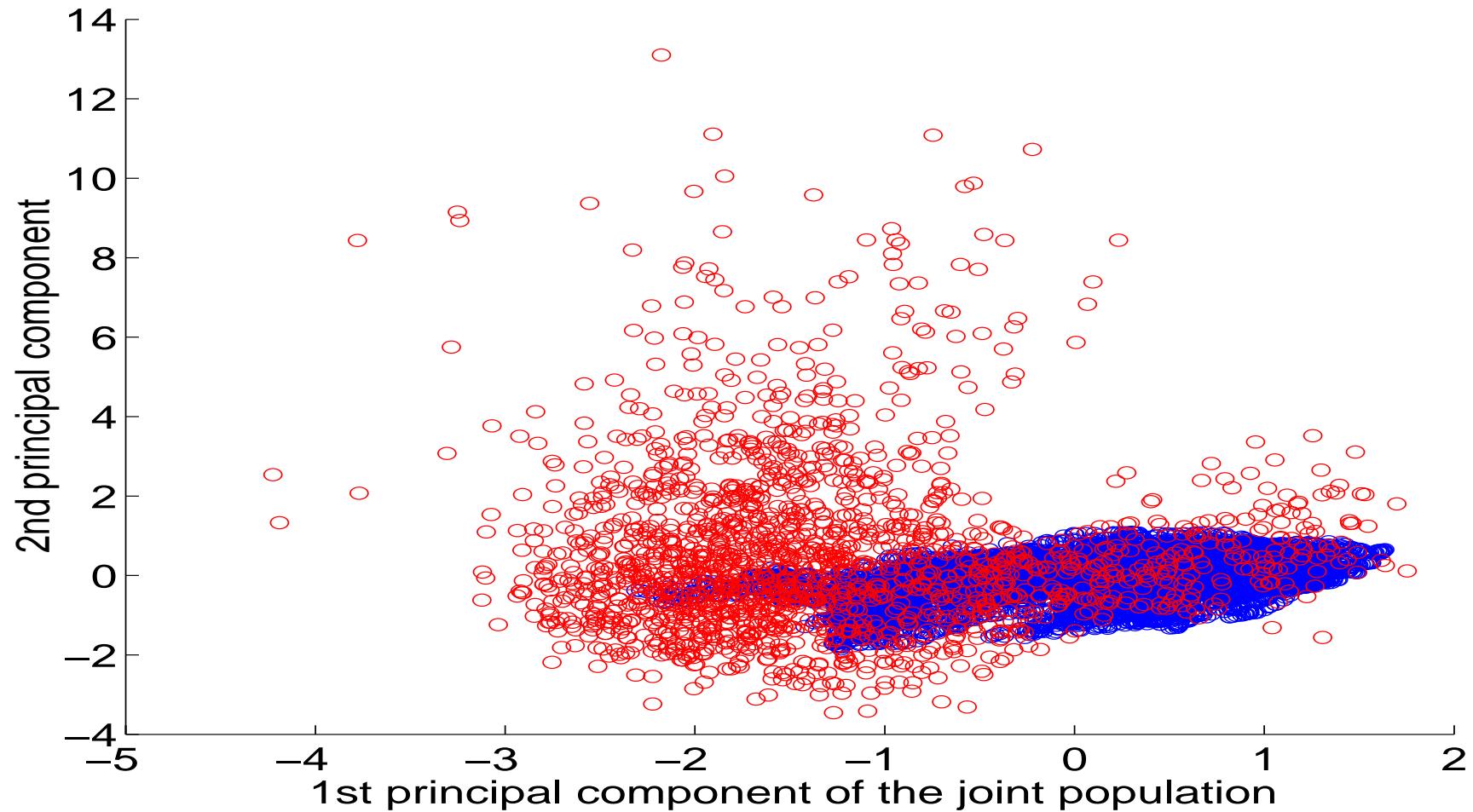
**NOAA-15 (19 orbits, ~FY 2000)**

	Down-track offset	Cross-track offset
AMSU-A1	$ \text{offset}  < \sim 5 \text{ km}$	$ \text{offset}  < \sim 5 \text{ km}$
AMSU-A2	$ \text{offset}  < \sim 5 \text{ km}$	16 km to the right
AMSU-B	0-10 km to the front	0-2 km to the right

# **Climate distribution of 1761 SATIGR radiosondes**

<b>Climate type</b>	<b>No. of RAOBs</b>
Tropical type atmospheres	322
Mid-latitude type-1 atmospheres	388
Mid-latitude type-2 atmospheres	354
Polar type-1 atmospheres	104
Polar type-2 atmospheres	593

# A comparison of the SATIGR and AIRS radiosondes



# NAST hyperspectral system channels

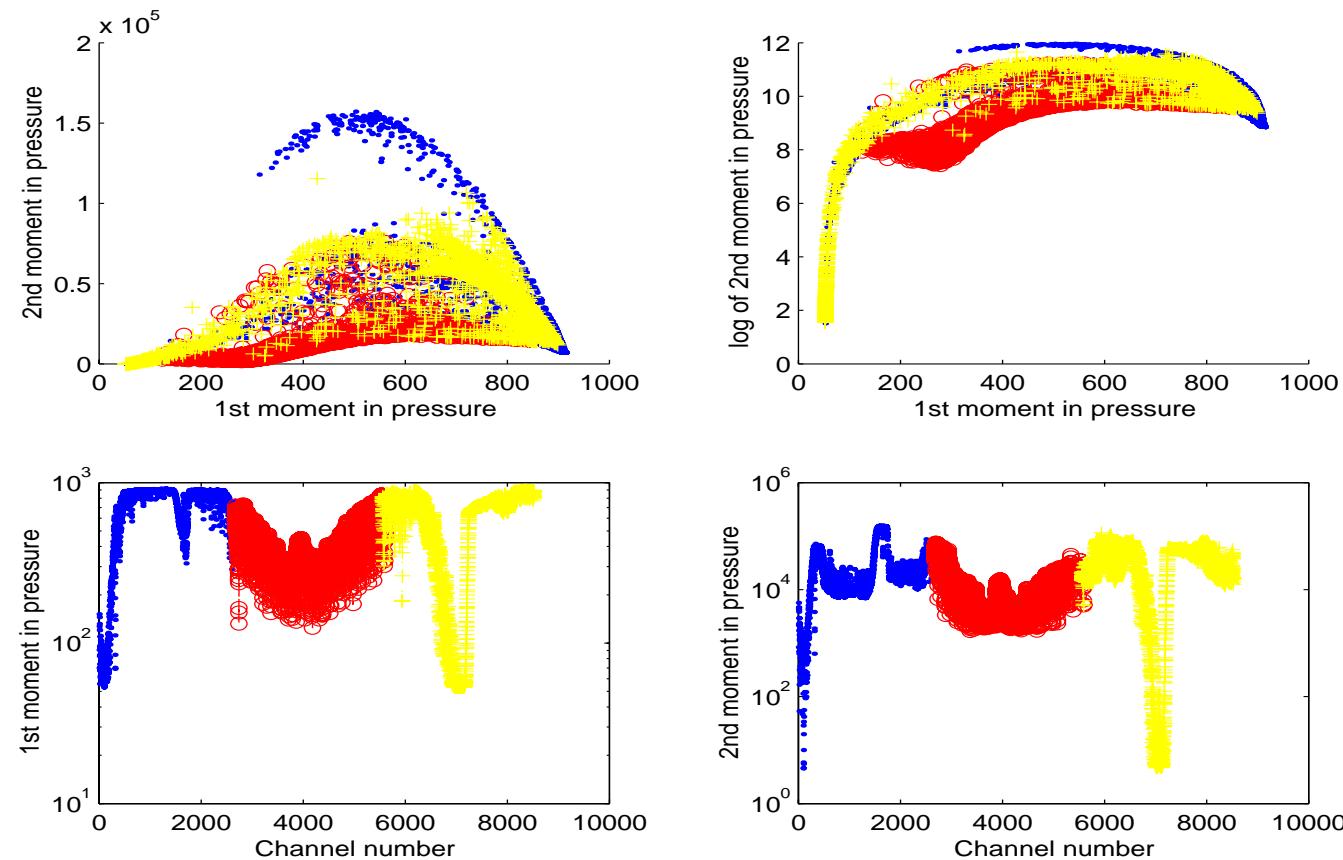
- **Microwave frequencies**

- Temperature:  $51.7, 52.8, 53.7, 54.4, 54.9, 55.5, 55.9$  and  $118.75 \pm \{0.23, 0.4, 0.8, 1.2, 1.6, 2.1, 2.3\}$  GHz. (NAST)
- Water vapor:  $183 \pm \{1, 3, 7\}$  and 220 GHz (MIR).
- Window: 50.3 and  $118.75 \pm 3.5$  GHz (NAST); 89 and 150 GHz (MIR).

- **Infrared wavelengths**

- 9000 channels,  $3.68 - 16.13\mu m$ .
- Reveals temperature, water vapor, trace gases, and window radiances.

# Weighting function 1st and 2nd moment, and channel number scatter plots



Chan 1:  $16.13\mu m$ , Chan 9000:  $3.68\mu m$

# Reduction of dimensionality for NAST-I

1. Start with all 9000 spectral channels.
2. Keep 3000 channels whose weighting function second moments are the sharpest at each of 50 altitudes for each of three bands:  $3.68 - 4.81\mu m$ ,  $4.81 - 7.76\mu m$ , and  $7.76 - 16.13\mu m$ .
3. Normalize all 3000 channels to have zero mean and unit variance; instrument noise = 0.25.
4. Compress training ensemble of 3000 channels to a 100-element vector using PCA, capturing 96.7% of the variance.

# Training data: NAST/MIR

## Wavelength dependence of surface temperature

	Microwave	Infrared
Distribution		Gaussian
Mean		RAOB surface air measurement
Std. deviation		$\sigma = 3^\circ K$
$K(f_1^\dagger, f_2) =$	$\sigma^2 e^{\frac{\ln 0.5}{130}  f_2 - f_1 }$	$\sigma^2$

## Wavelength dependence of surface emissivity

	Microwave	Infrared
Parameterization of model	22 parameters, 1 per channel	7 param; piecewise-linear over 9000 chans.
Distribution of parameters	Uniform, range=[0.35, 1]	Gaussian, clipped at 1 $\bar{\epsilon} = 0.95, \sigma = 0.25$
$K(f_1, f_2)^* =$	$\frac{1}{9.5}(10.5 - \frac{f_2}{f_1})$	Computed from AIRS‡.

† frequency is in GHz

‡ S. Y. Lee et al. *AIRS Simulation Study: Development of Simulation Algorithms for the Atmospheric Infrared Sounder*. EOS Supplement. vol 74. 1993. pp. 43–72.

\* Assume  $f_2 > f_1$ .

# Neural Networks

**Microwave:** 22 normalized BT inputs, 2 hidden layers of 30 and 15 nodes, 14 pressure-level outputs of relative humidity 1013 – 310 mbar.

**Infrared:** 9000 radiance channels compressed to 100 inputs, 2 hidden layers of 30 and 15 nodes, 20 pressure-level outputs of relative humidity 1013 – 130 mbar.

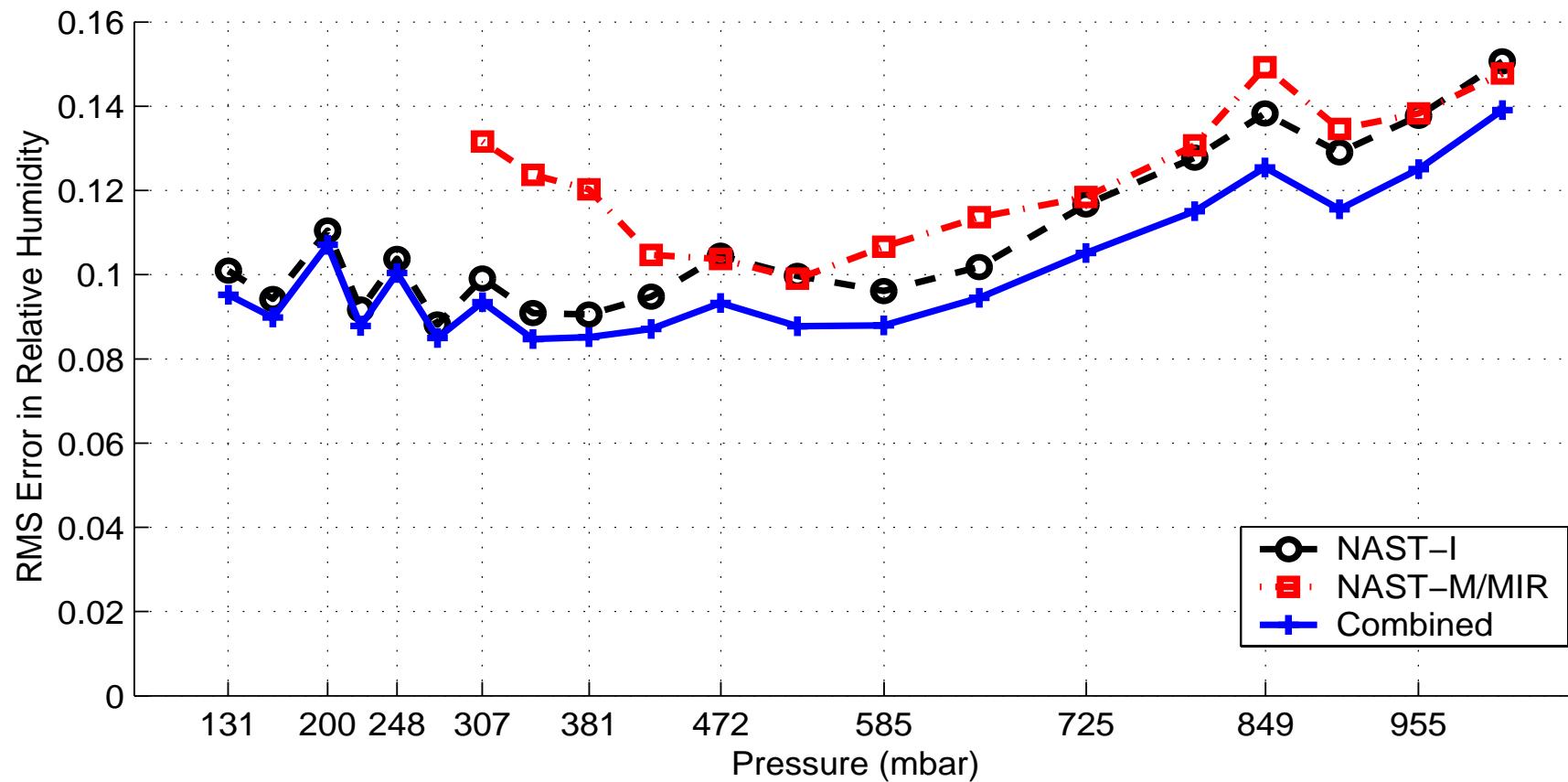
Infrared flight data contained negative radiances, which cannot be converted to BT, so radiances were input to the net.

Only one final network was trained.

Network performance is largely independent of surface temperature and emissivity covariances and number of output pressure levels.

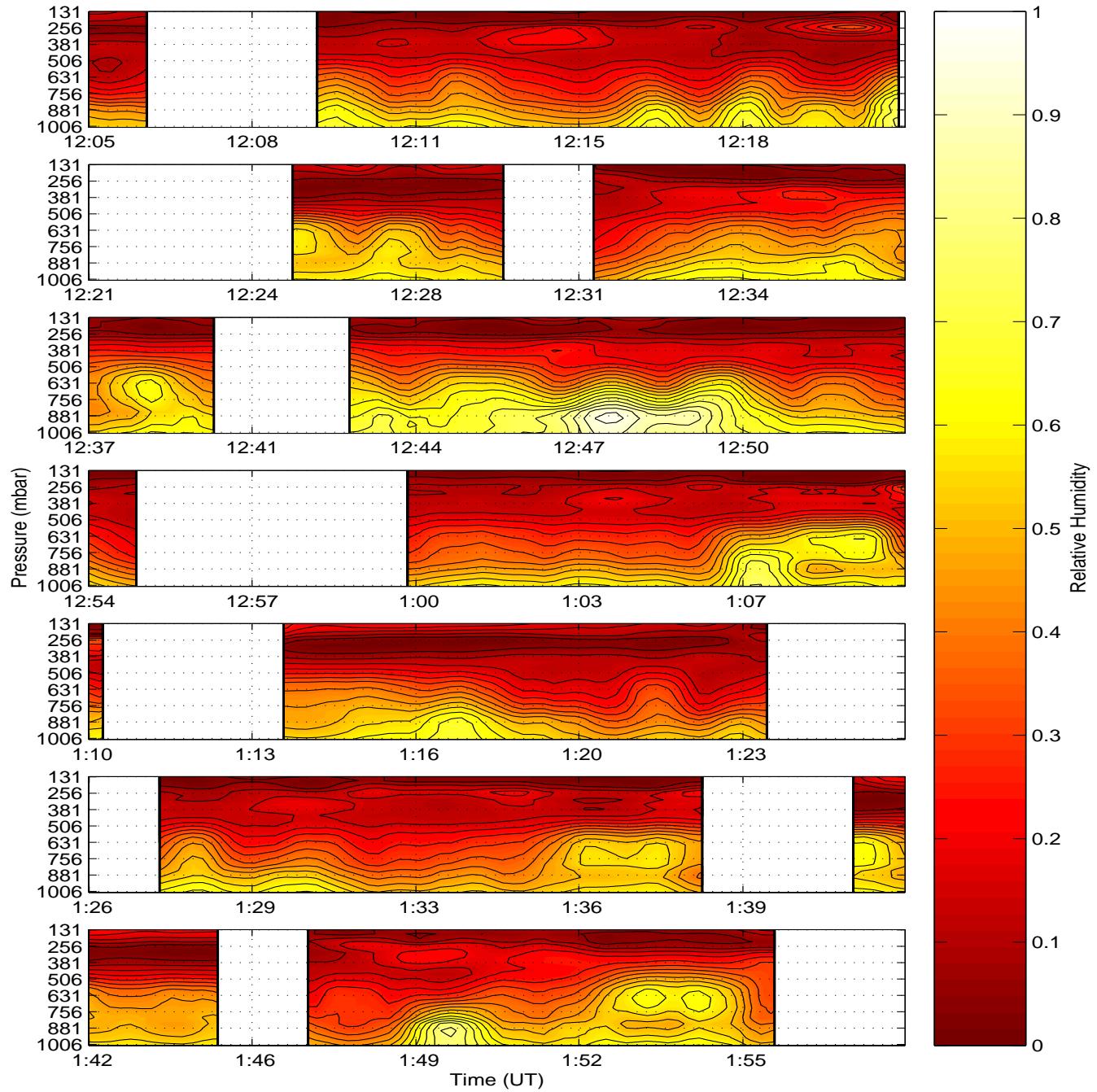
# Relative humidity rms retrieval errors

## based on 1761 SATIGR radiosondes



# NAST-I relative humidity retrievals, September 13, 1998

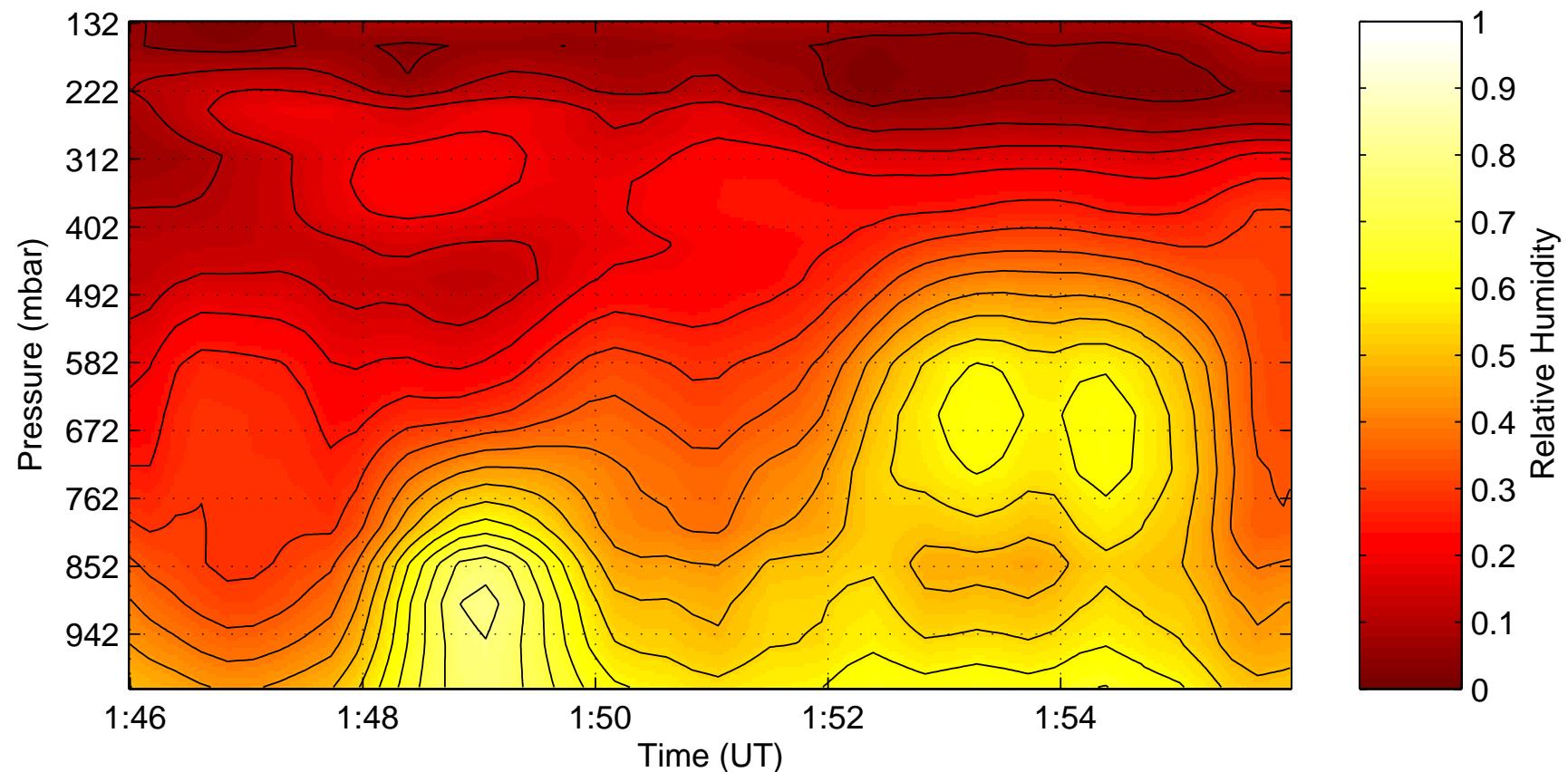
Contours represent a 0.05 change.



# Infrared nadir retrieval over Andros Island

Pass #2 for September 13, 1998.

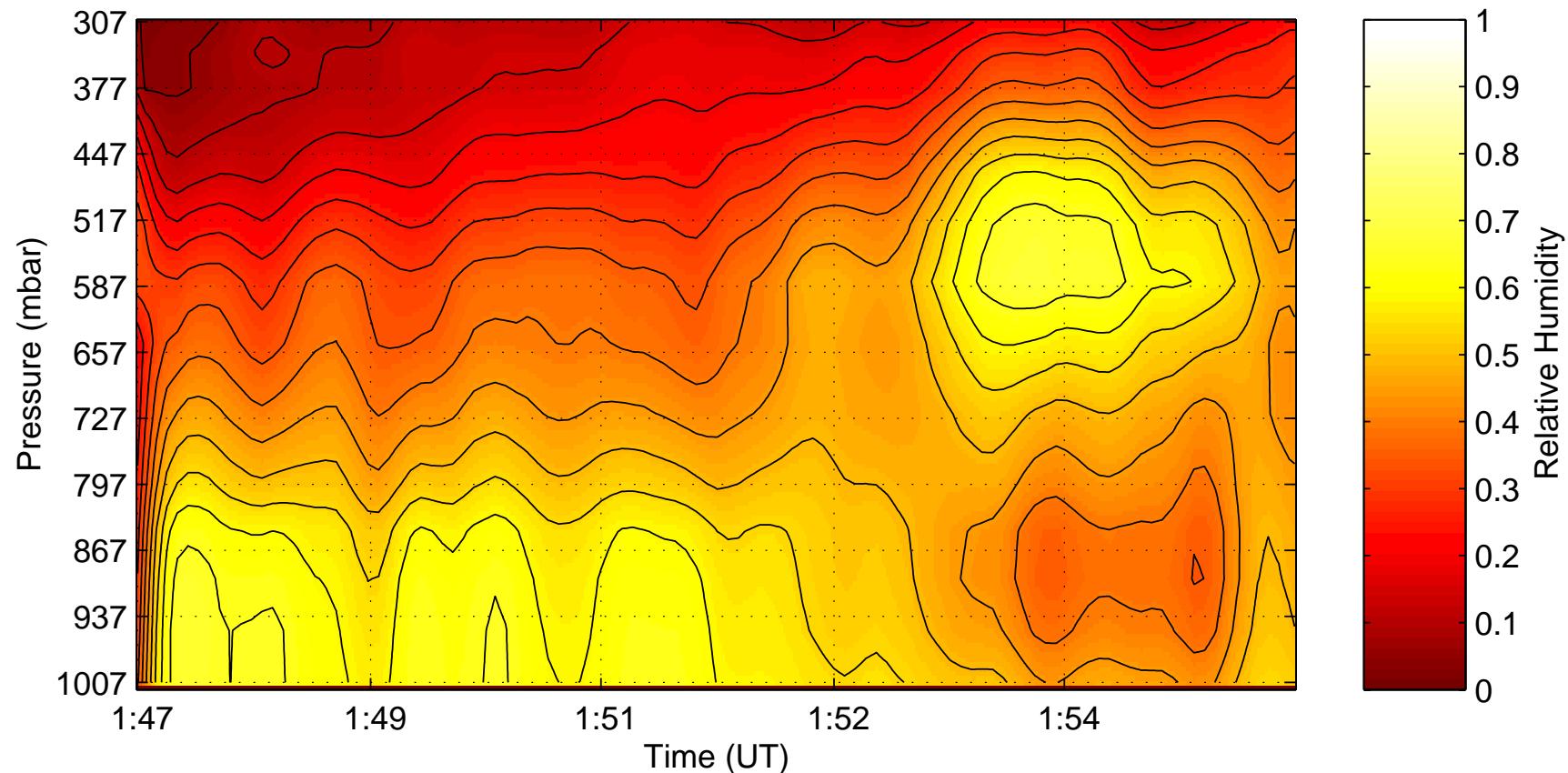
Contours represent a 0.05 change.



# Microwave nadir retrieval over Andros Island

Pass #2 for September 13, 1998.

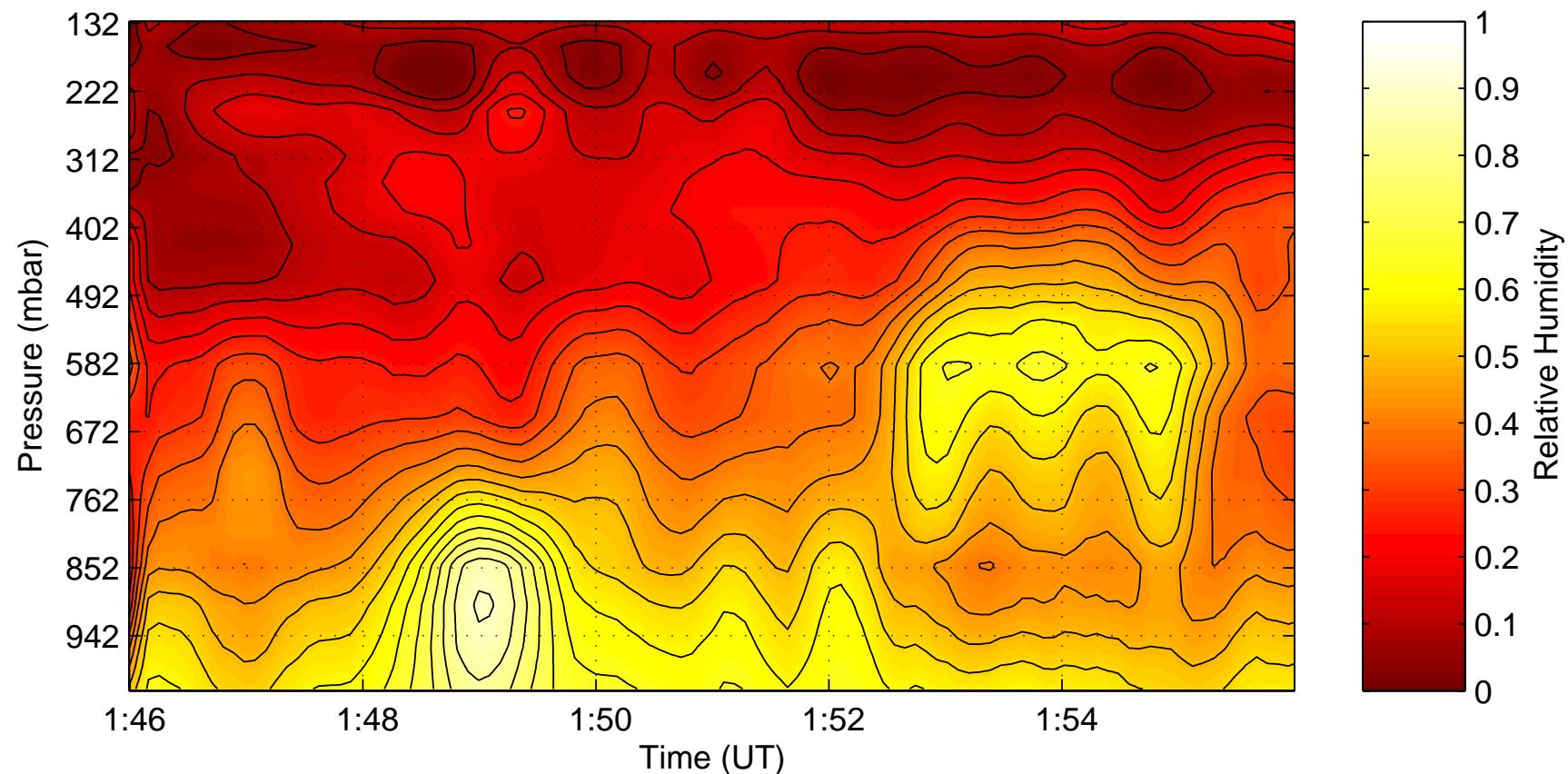
Contours represent a 0.05 change.



# Combined infrared and microwave nadir retrieval over Andros Island

Pass #2 for September 13, 1998.

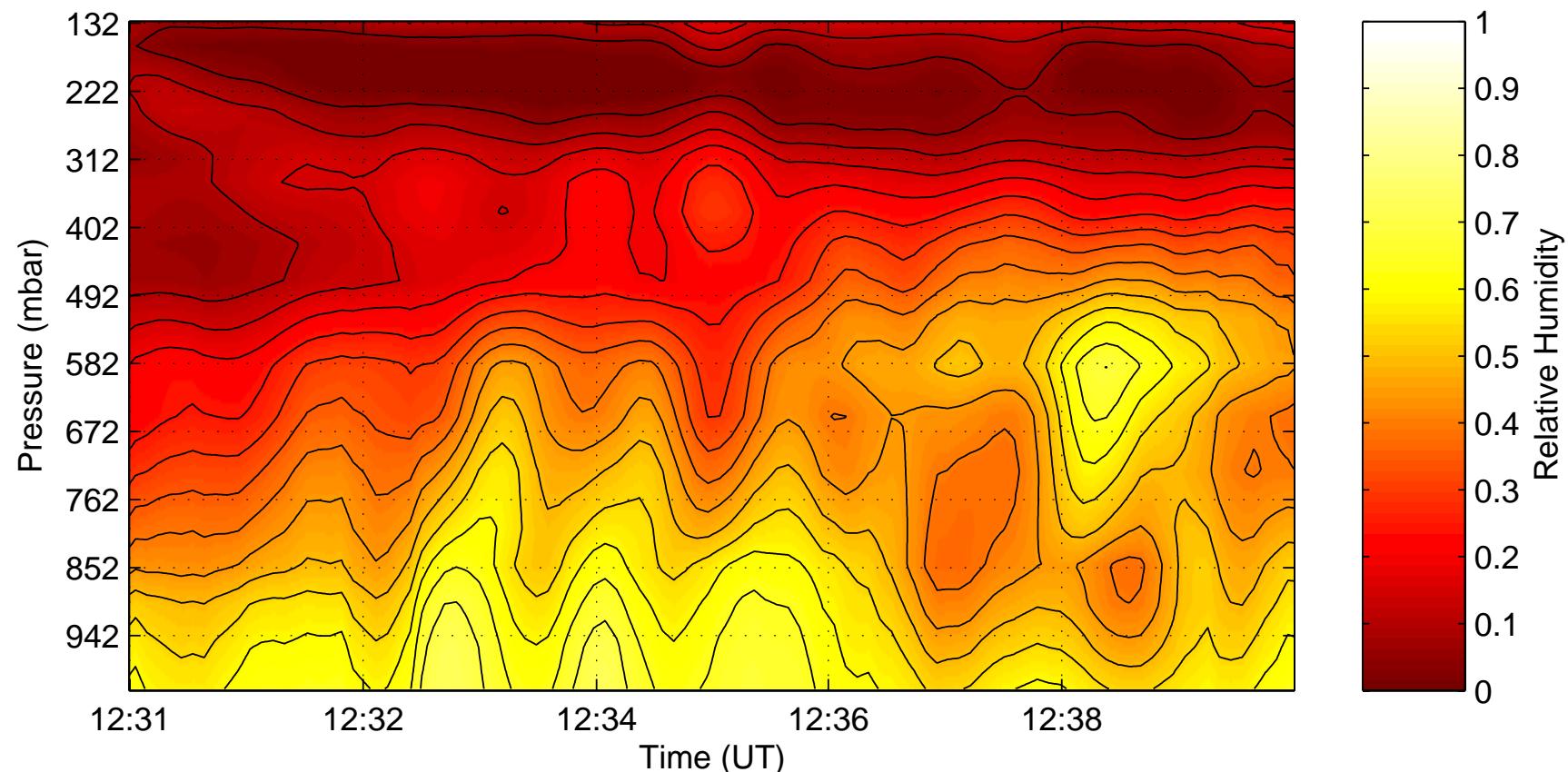
Contours represent a 0.05 change.



# Combined infrared and microwave nadir retrieval over Andros Island

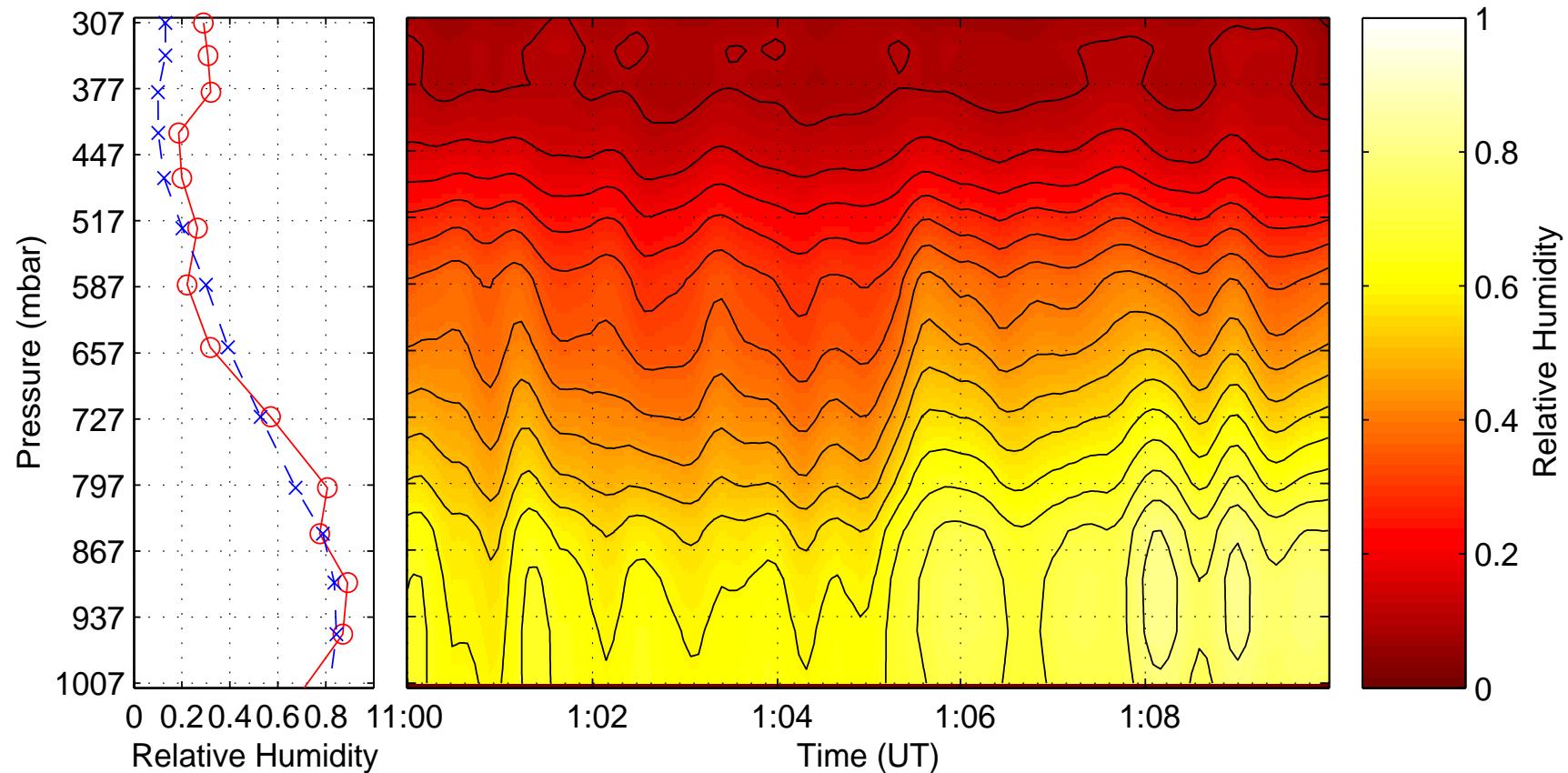
Pass #1 for September 13, 1998.

Contours represent a 0.05 change.



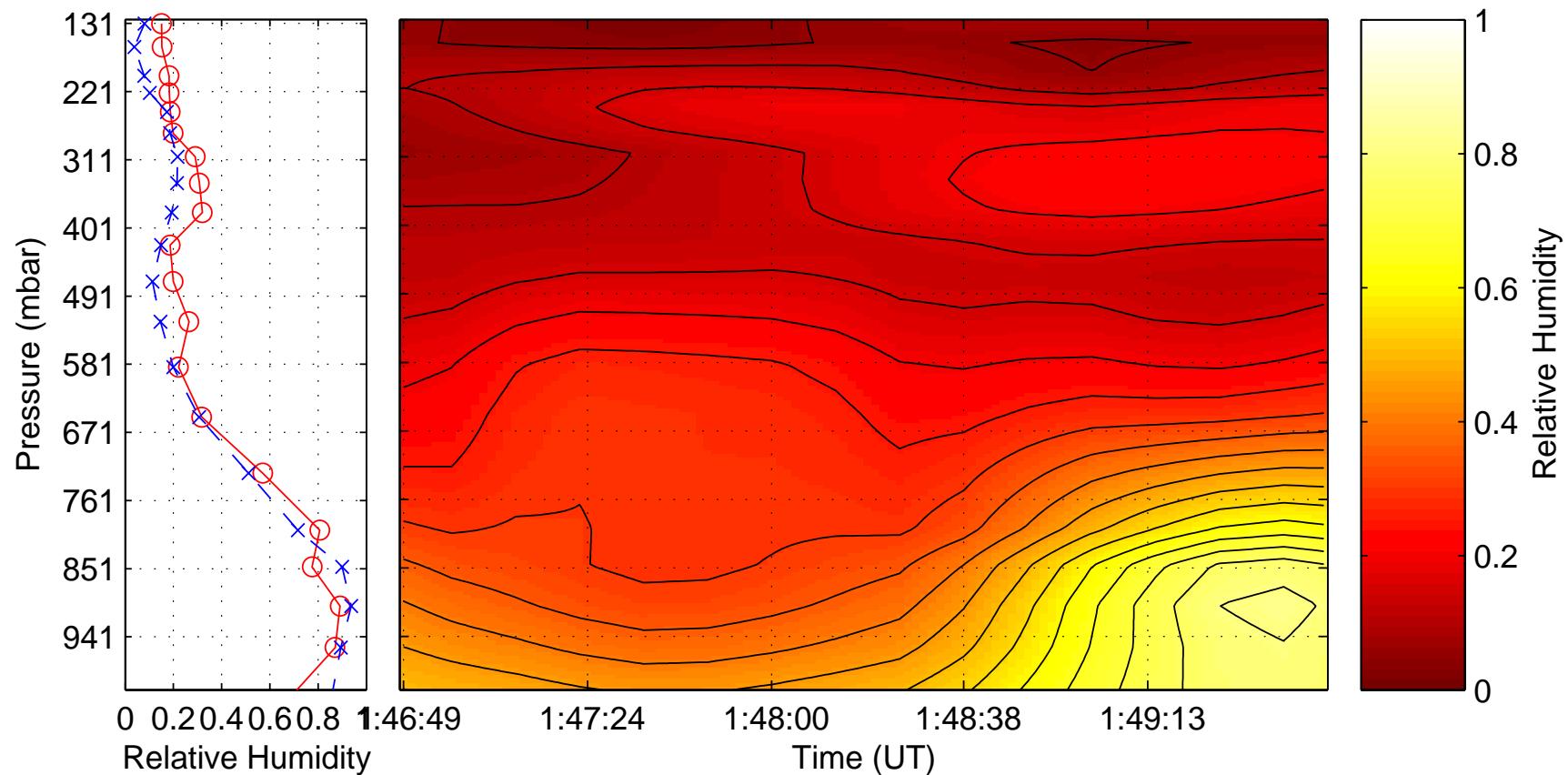
# Microwave/RAOB comparison for September 13, 1998

Average of 6 RAOBs (o) vs. best-fit retrieval (x)  
at 1:09 UTC. Rms error is 8.86%



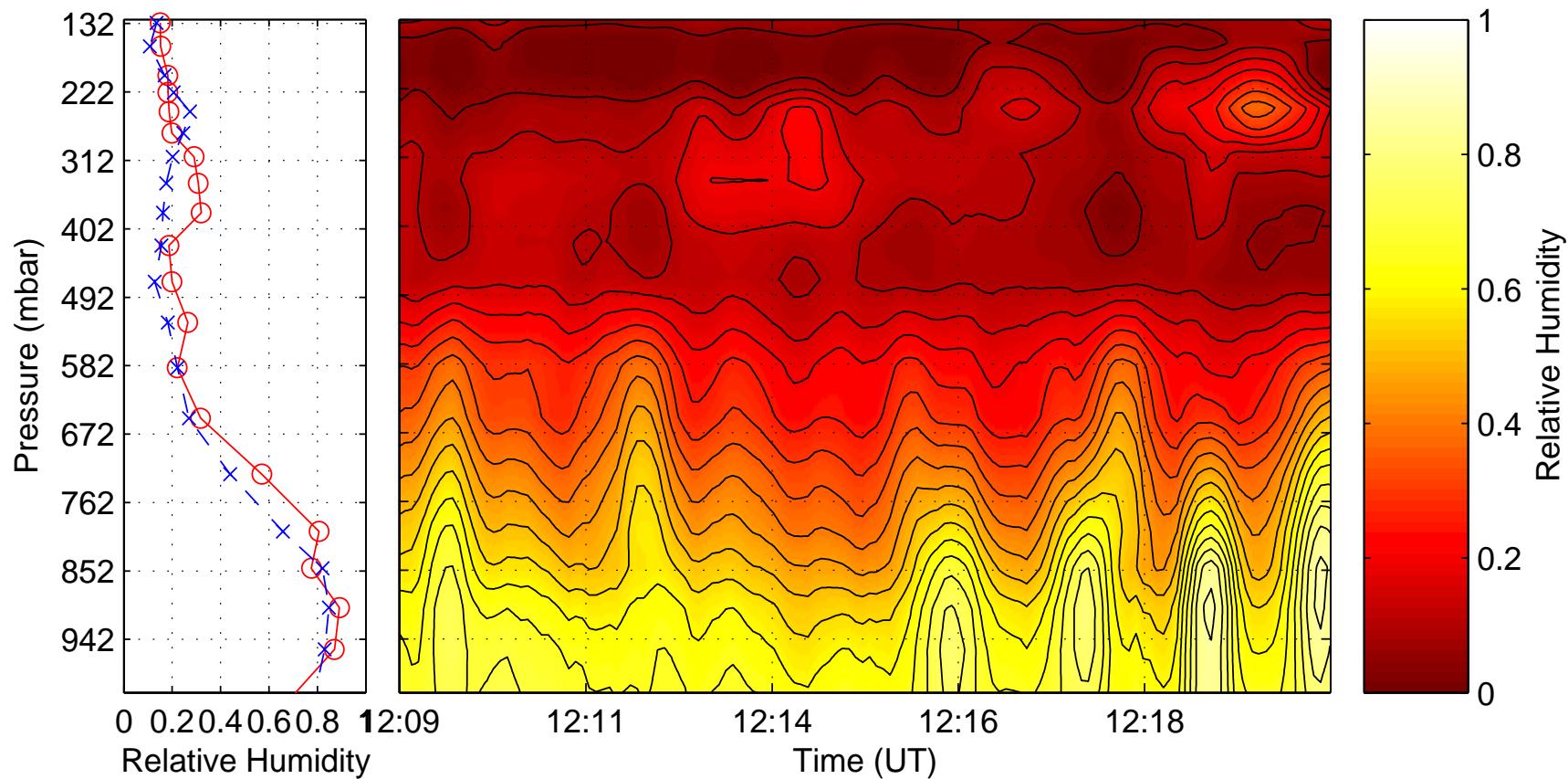
# Infrared/RAOB comparison for September 13, 1998

Average of 6 RAOBs (o) vs. best-fit retrieval (x)  
at 1:50 UTC. Rms error is 8.44%



# Combined infrared and microwave/RAOB comparison for September 13, 1998

Average of 6 RAOBs (o) vs. best-fit retrieval (x)  
at 12:15 UTC. Rms error is 8.06%



## Applying simulation-based retrievals to flight data

The simulation used measured instrument noise in both cases, with an additional uncorrelated bias noise of  $1.25^{\circ}K$  in the infrared case.

Microwave: RAOB adjustment of  $-1$  to  $4^{\circ}K$  applied to flight data, computed from the average of 2 flights.

Infrared: No raob adjustment to the flight data! The network is trained to estimate profiles on an uncalibrated instrument that has large random biases channel-to-channel.

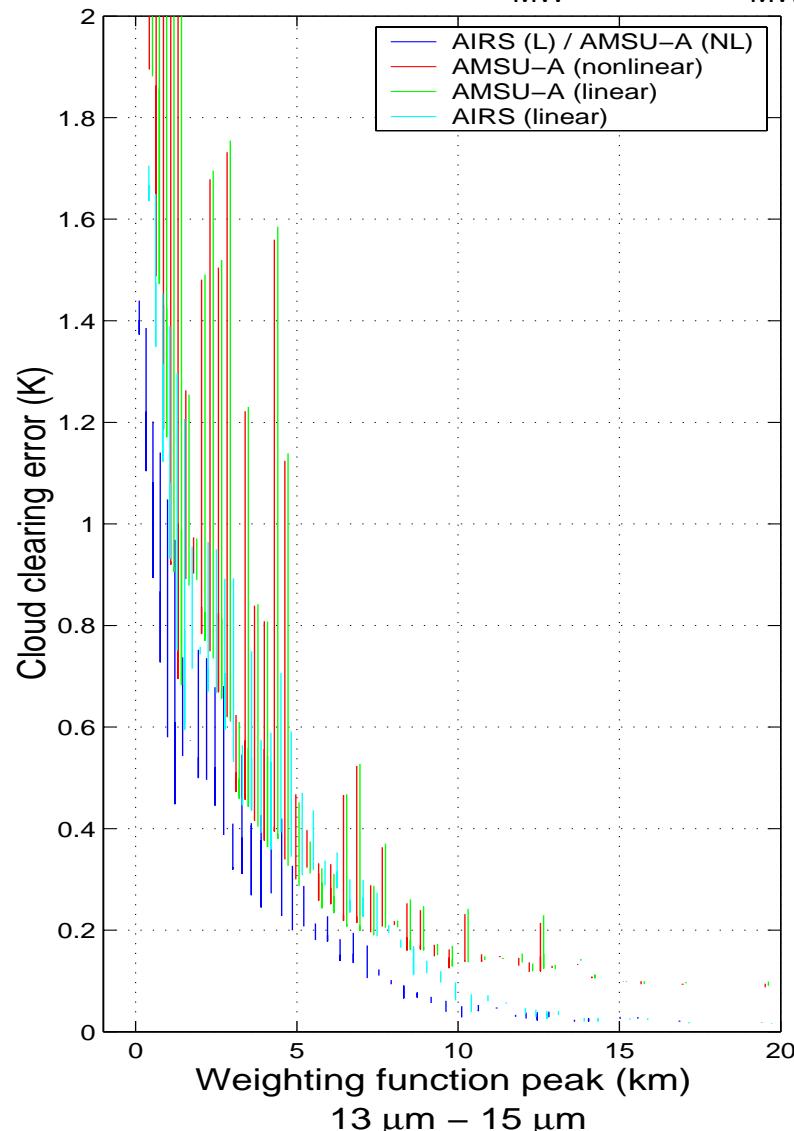
## **Applying simulation-based retrievals to flight data: What didn't work for NAST-I?**

Unreasonable retrievals resulted from linear regression on: 1) 9000 channels, 2) 3000 selected channels, and 3) 100 principal components, all computed on the same simulation and flight data, which had given reasonable results with a neural net.

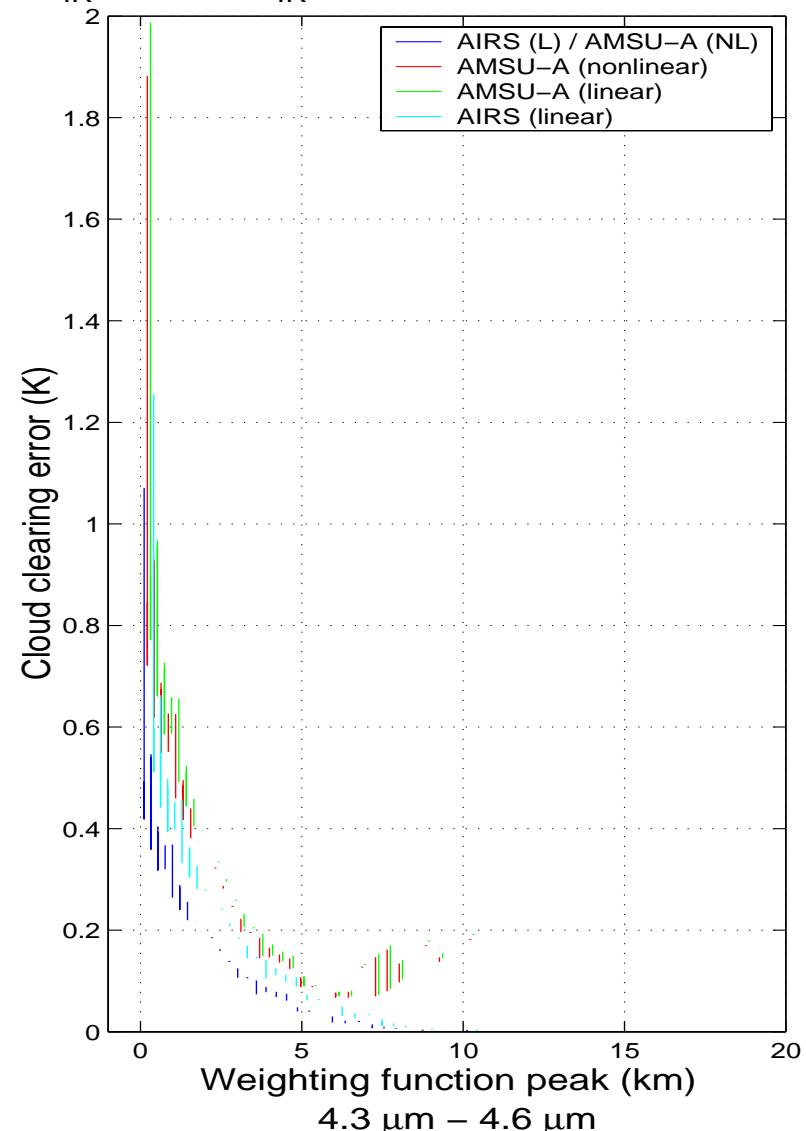
Removing a RAOB-derived bias from the flight data did not help.

Adding a  $1.25-5^{\circ}K$  diagonal noise covariance matrix to the data covariance matrix for the 3 linear regressions yielded improved, but still unreasonable output.

**AIRS Cloud Clearing Error (Simulation – 12000 GCM Profiles, Grey Surface)**  
 $\mu_{MW} = 0.940, \sigma_{MW} = 0.050, \mu_{IR} = 0.970, \sigma_{IR} = 0.025$

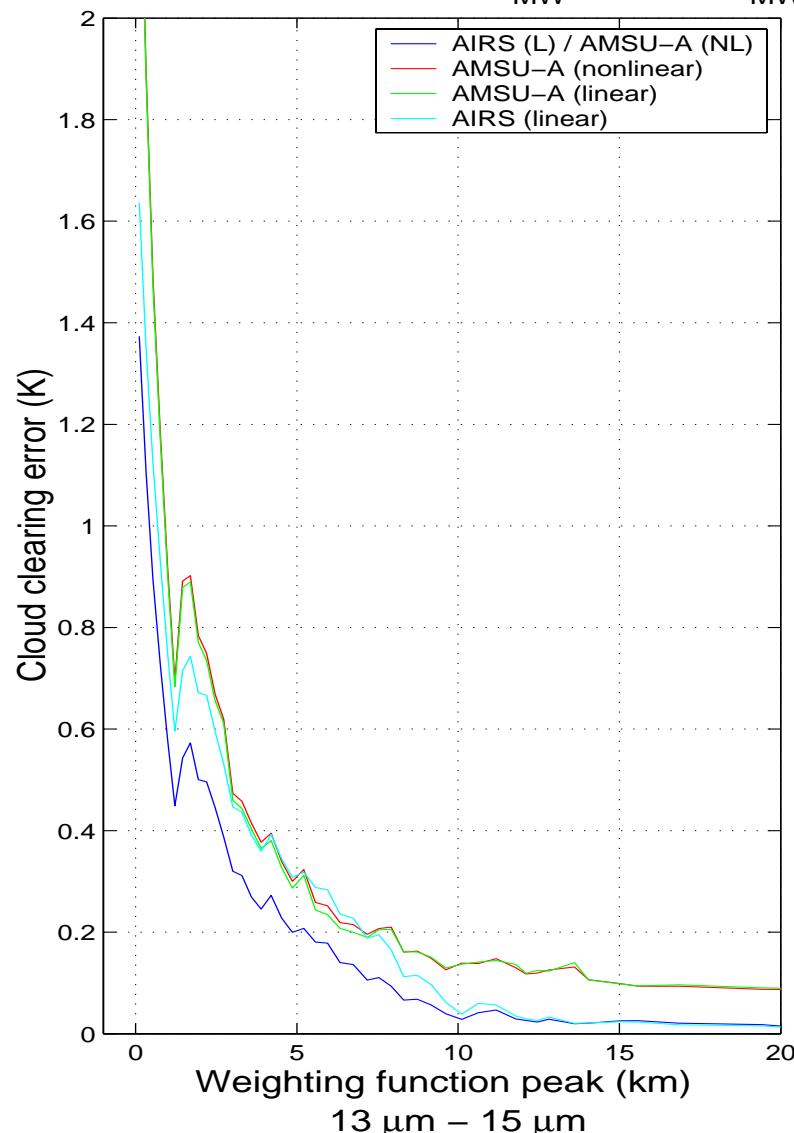


June 12, 2001

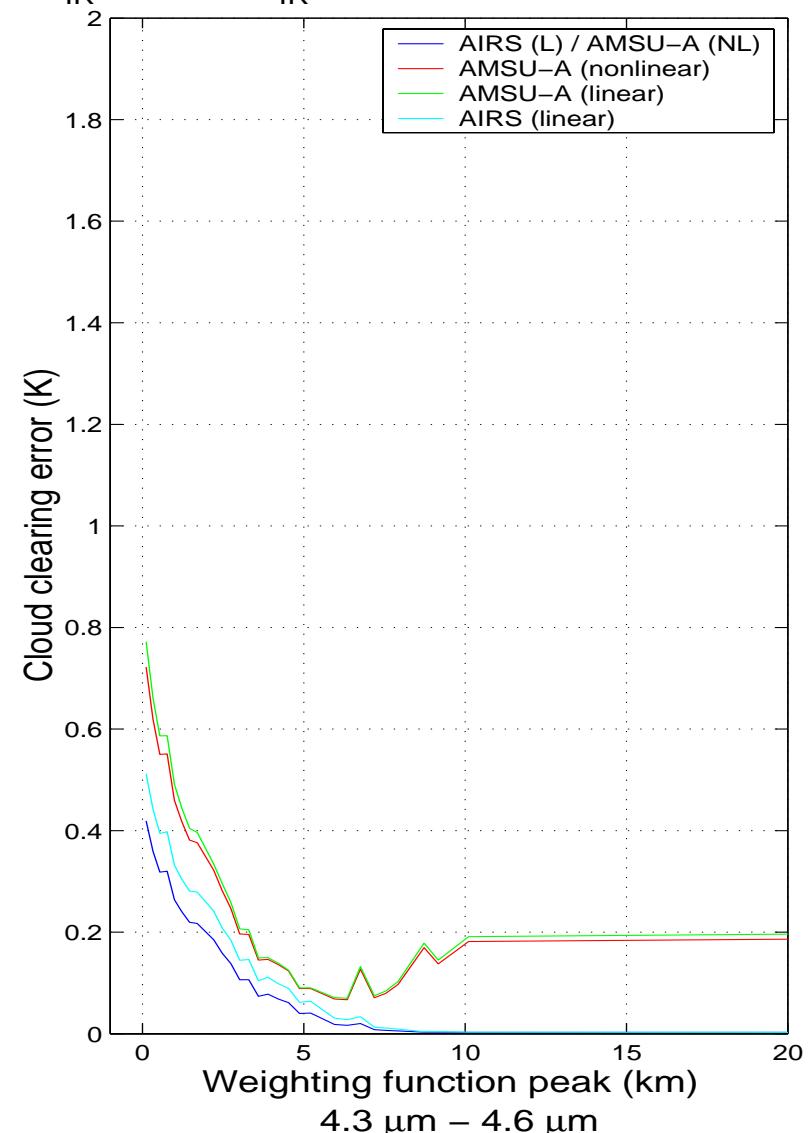


WJB

**AIRS Cloud Clearing Error (Simulation – 12000 GCM Profiles, Grey Surface)**  
 $\mu_{MW} = 0.940, \sigma_{MW} = 0.050, \mu_{IR} = 0.970, \sigma_{IR} = 0.025$



June 12, 2001



WJB

### AIRS, 15- $\mu\text{m}$ Weighting Functions That Peak Near 1.25 km Altitude

